

allow a full survey of the low energy region, so in order to check the Born values in this region the differential cross-section (per unit energy range of the final state) has been calculated in two particular cases, for lead ($Z = 82$) for an incident electron of total energy $E_0 = 3mc^2$, losing energy $h\nu = 1.5mc^2$ and $1.95mc^2$.

The cross-sections Φ are given for these two cases and for comparison the values obtained using the Born approximation are inserted (Bethe and Heitler, *loc. cit.*, eqn. (15)).

Energy loss	$1.5mc^2$	$1.95mc^2$
$\Phi \times 10^{24}$	13	8
$\Phi \times 10^{24}$ (Born)	9.9	1.8

The values given should be correct to about 10 per cent. It appears that in this case the Born approximation gives fairly good results, except towards the short wave limit, $h\nu \rightarrow E_0 - mc^2$, where it is much too low. This is to be expected, as the wave function of the electron in the final state can no longer be regarded as an approximately plane wave.

As suggested by Heitler², it can also be shown that for the Dirac electron, as in the non-relativistic theory of Sommerfeld, the cross-section approaches a finite value at the short wave limit. We may expect that, as in the analogous case of pair production by a beam of γ -rays⁴, the error of the Born values will decrease rapidly with increasing E_0 and decreasing atomic number, except near the short wave limit.

Comparison with experiment is as yet impossible, but it may be noted that Klarman and Bothe⁵, using electrons of mean total energy about $3.5mc^2$ scattered in xenon and krypton, have obtained results indicating energy losses about 3-5 times those given by the Born approximation.

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¹ Jaeger and Hulme, *Proc. Roy. Soc., A*, **153**, 443 (1936).

² Bethe and Heitler, *Proc. Roy. Soc., A*, **146**, 83 (1934).

³ "Theory of Radiation", p. 171.

⁴ NATURE, **137**, 781 (1936).

⁵ *Z. Phys.*, **101**, 489 (1936).

Absorption Spectra Evidence of the Decomposition of the Ground Term of Nd^{+++} Ion due to Crystalline Fields

PARAMAGNETIC ions in crystals are subject to electrostatic crystalline potentials the symmetry properties of which depend mainly on the local arrangement of other atoms around the ion. For example, six oxygen atoms grouped octahedrally around the ion, as in $NdCl_3 \cdot 6H_2O$ and $Nd_2(SO_4)_3 \cdot 8H_2O$, give rise to a field of cubic symmetry of the type $D(x^4 + y^4 + z^4)$. A general method for determining the decomposition of the energy levels of the ion in such a field has been worked out by Bethe¹, and Van Vleck² has utilized this theory to account for the broad features of the temperature variation of the magnetic susceptibility of crystals. Penney and Schlapp³ have considered the rare earth salts in detail. From the temperature variation of the mean susceptibility, as measured by Gorter and de Haas, they find that the level $^4I_{9/2}$ of the free ion is split into three groups of levels at 0, 244 and 610 cm^{-1} . Spedding⁴, by direct spectroscopic measurements of the absorption spectra of this crystal, finds levels at 0, 77 and 260 cm^{-1} . From these results the conclusion is drawn that the levels predicted by Schlapp and Penney are not found, but the levels actually

observed have the same relative, but only one third overall, separation. Determining the value of the constants in Penney and Schlapp's equations, Spedding finds that his results are in better agreement with the susceptibility measurements of Zernicke and James, and of Selwood.

I wish to report on the result of certain investigations carried out in my laboratory by Mr. P. C. Mukherji on the absorption spectra of crystals of $NdCl_3 \cdot 6H_2O$, which are in good agreement with the predictions of Penney and Schlapp's theory. The detailed results are being published in the *Indian Journal of Physics*. It has been found that in the region of 5000 Å ., there is an absorption band consisting of seven intense lines, and accompanied on the longer wave-length side by a similar group of six faint absorption lines.

Strong lines	Weak lines	Interval
19,144 cm^{-1}	18,897 cm^{-1}	247 cm^{-1}
19,095	18,852	243
19,082	18,820	262
19,035	18,788	247
19,001	18,752	249
18,972	—	—
18,940	18,691	249
	Mean	249 cm^{-1}

On reducing the temperature of the crystal to that of liquid oxygen, it is found that while the sharpness of the faint components increases, their intensities diminish, so that they can be observed at the low temperature with a comparatively thick crystal only ($t = 2.5$ mm.). The weak lines seem, therefore, to be due to transitions from a lower excited level of the ground term of the Nd^{+++} ion, and the observed frequency difference of 249 cm^{-1} seems to be in good agreement with the calculated value of 244 cm^{-1} found by Penney and Schlapp. This result appears to be a definite optical verification of the splitting up of a term in a crystalline field as calculated from purely magnetic data.

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April 28.

¹ *Ann. Phys.*, **3**, 133 (1929).

² "Theory of Electric and Magnetic Susceptibilities" (Oxford, 1932).

³ *Phys. Rev.*, **41**, 194 (1932).

⁴ *J. Chem. Phys.*, **5**, 160 (1937).

THE interpretation of the absorption spectra of rare earth crystals, as given by Spedding and his collaborators¹, and by Prof. Bose in the above letter, to us seems too simple to be true. Spedding claims that his measurements on the absorption spectrum of crystals of the type $X_2(SO_4)_3 \cdot 8H_2O$, where X is a rare earth element, can be quantitatively explained on the basis of a crystalline potential $D(x^4 + y^4 + z^4)$. In the case of Pr^{+++} , for example, this potential by no means removes all the degeneracy of the lowest state, 3H_4 , of the free ion, but gives a pattern consisting of a single, a doubly-degenerate, and two triply-degenerate levels. Spedding actually finds four low-lying levels, and identifies them with this pattern. As he points out, any terms in the potential function not of cubic symmetry will remove the degeneracy of the triple levels in first approximation, and the fact that no trace of such doubling or tripling can be detected, he takes to mean that terms other than those of cubic symmetry are practically absent.